Characterization of Surface Directional Reflectance Properties from Airborne Angular Reflectance Measurements to Improve the Accuracy and Consistency of Long-Term Data Records

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NASA P-3, CAR, & CANS

NASA P-3B Aircraft

Laboratory Calibration of CAR

CANS

41 CM

72 CM

InSb DETECTOR ASSEMBLY

ELECTRONICS COMPARTMENT

SCAN MIRROR

UP

FORWARD

39 CM

FILTER WHEEL HOUSING

TELESCOPE SECONDARY MIRROR

TELESCOPE PRIMARY MIRROR
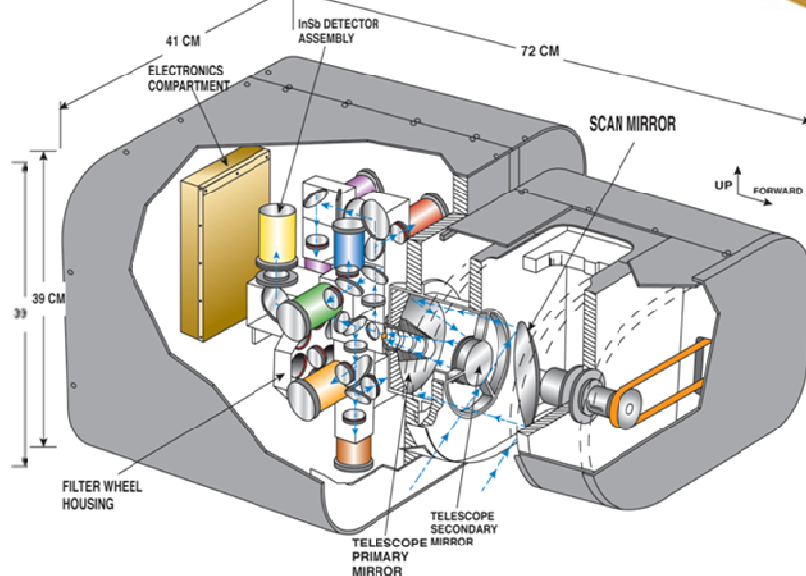
Cloud Absorption Radiometer (CAR) Parameters

Angular scan range	190°
Instantaneous field of view	17.5 mrad (1°)
Pixels per scan line	382
Scan rate	1.67 scan lines per second (100 rpm)
Spectral channels (μm; bandwidth (FWHM))	14 [a] (8 continuously sampled and last six in filter wheel): 0.340(0.009), 0.381(0.006), 0.472(0.021), 0.682(0.022), 0.870(0.022), 1.036(0.022), 1.219(0.022), 1.273(0.023), 1.556(0.032), 1.656(0.045), 1.737(0.040), 2.103(0.044), 2.205(0.042), 2.302(0.043)
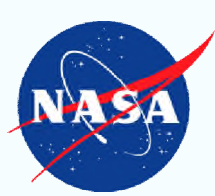
The CAR has participated in many field campaigns of varying sizes and complexity (e.g., ARCTAS 2008, CLASIC 2007, CLAMS 2001, and SAFARI 2000).
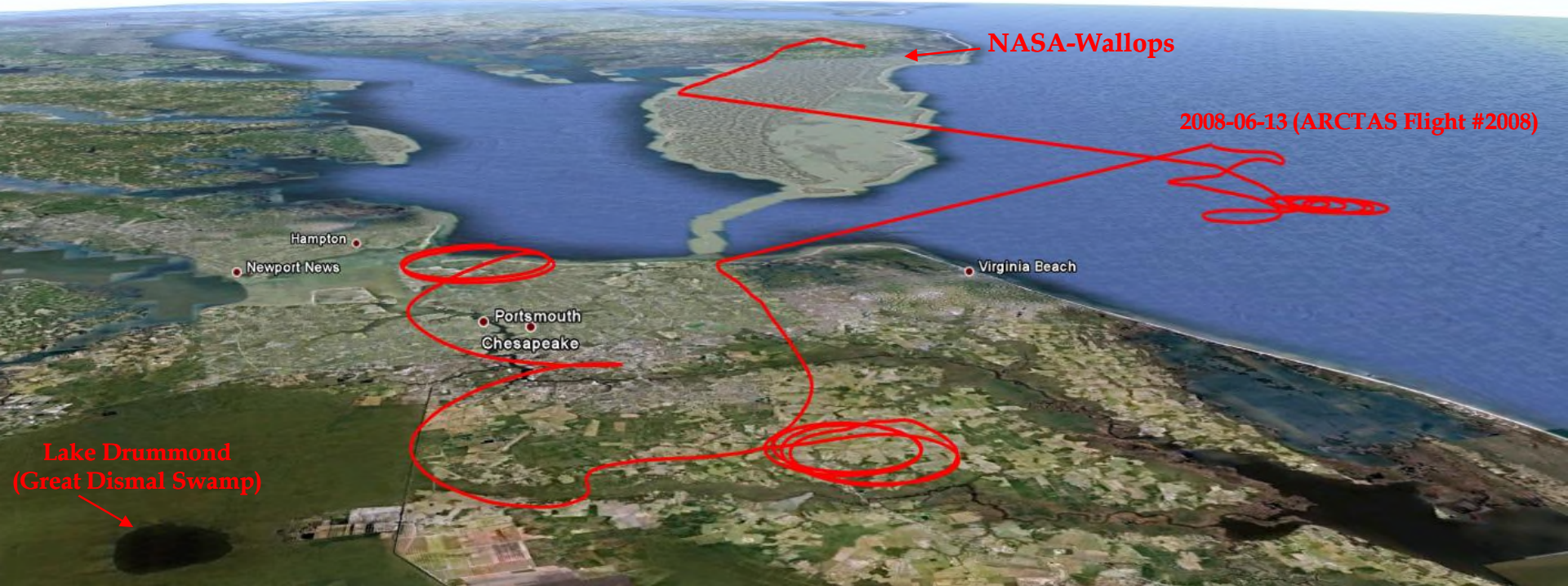

- ***Long-Term Approach:*** Prioritize on targets of opportunity where a long-term focus on *in-situ* data collection and Land Product Cal/Val activities has been established.

- Coincident observations over ***5 EOS Land Validation Core Sites*** and ***2 CEOS-LANDNET*** calibration sites.

- Level-1B datasets available over: ***sea ice, snow, tundra, croplands, urban, forests, savannas, salt pans, and permanents wetlands.***

Cloud Absorption Radiometer: Focus Areas

| Focus Area	**Current** and **Potential**§ Applications	Campaign/ Project	Key Players[†]
Cryospheric Science	• Retrieval of snow BRDF/albedo/grain size over sparse vegetation and arid environments; • Satellite aerosol retrieval over snow; • Surface energy balance of seasonal snow cover for snowmelt estimation. • Characterize the effects of blowing snow & cloud forward scattering on altimetry (Lidar) measurements to evaluate the imprint of climatic changes on ice dynamics (e.g., flow of ice & mass balance).	ARCTAS, IceBridge§, ICESat	Lyapustin et al. (2010) Gatebe et al. (2010) Arnold et al. (2002) **Collaborators:** Hall, Kahn, Schaaf, Yang.
Biospheric Science	• MODIS/MISR Land and Aerosol Product Cal/Val efforts; • Diurnal-to-seasonal characteristics of surface energy balance; • Retrieval of surface biophysical parameters (e.g., BRDF-Albedo, VI, and Clumping index) at multiple spatial scales and angular distributions; • Retrieval of vegetation structural parameters (e.g., leaf size, canopy height, and canopy roughness) over complex heterogeneous surfaces.	ARCTAS, CLASIC, INTEX-B, Skukuza, CLAMS, SAFARI 2000, TARFOX, SCAR-B, CLAMS	Román et al. (2010) Gatebe et al. (2003; 2010) Soulen et al. (2000) Tsay et al. (1998) **Collaborators:** Chopping, Fernandes, Georgiev, Hill, King, Lewis, Ni-Meister, Thome.
Freshwater/ Coastal & Marine Climate Science	• Retrieval of surface BRDF/albedo over aquatic biomes (e.g., coastlines, estuaries, ponds, and lakes) under clear and turbid waters. • Impact of anthropogenic forcing (e.g., ship wakes) on ocean energy balance.	ARCTAS-CARB, CLAMS, ARCTAS	Gatebe et al. (2005;2010)
Cloud & Smoke Radiative Properties	• Cloud/Smoke interior: Energy budget; Actinix flux; • Wildfire smoke: Effects of boreal/savanna fire regimes on atmospheric chemistry, global carbon cycling, and climate; • Precipitating cloud: Impact on land-atmosphere interactions and locally generated cumulus convection.	SCAR-B, SAFARI 2000, Skukuza, CLASIC, ARCTAS	Gatebe et al. (2003) King (1992) **Collaborators:** Ichoku, Marshak, Melnikova, Varnai.

[†]**Cited publications are available at: http://car.gsfc.nasa.gov/publications/**   §**Pending opportunity.**

Characterization of Surface Directional Reflectance Properties at the Chesapeake Bay Watershed (CBW)

NASA-Wallops

2008-06-13 (ARCTAS Flight #2008)

Hampton

Newport News

Virginia Beach

Portsmouth
Chesapeake

Lake Drummond
(Great Dismal Swamp)

Objective: *"To maximize data collection and minimize aircraft deployments."*

• Since CAR test flights are routinely carried out at NASA's Wallops Flight Facility, the instrument often flies over key terrestrial and maritime ecosystems in the CBW (e.g., permanent wetlands, marches, swamps, and estuaries).

MODIS Satellite Image
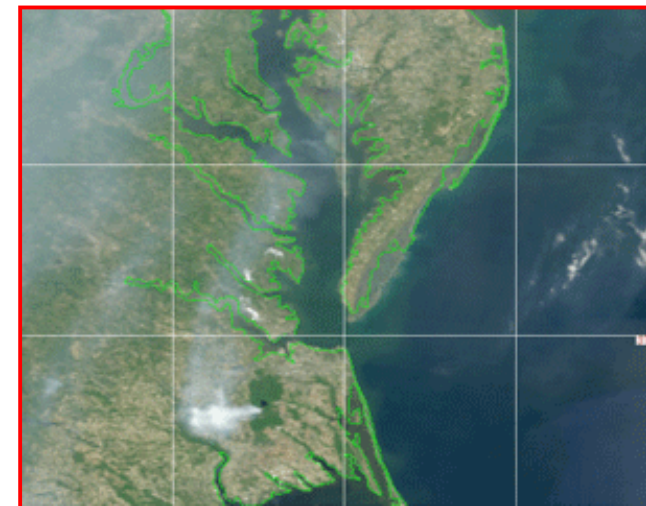
Objective: To directly map through measurement uncertainties from sensors to products.
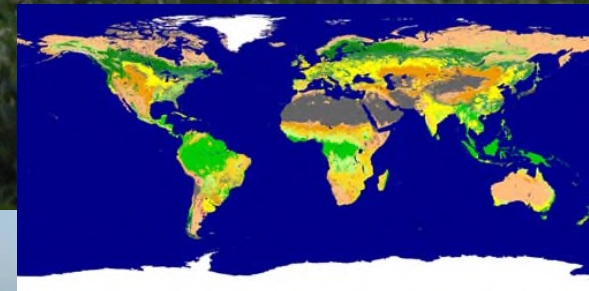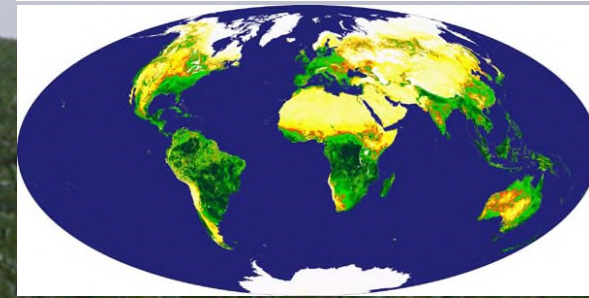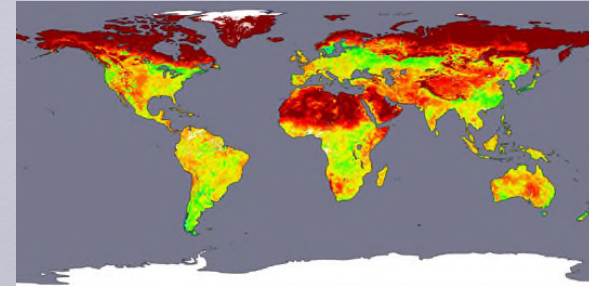
Relating point measurements…

…to global land products.

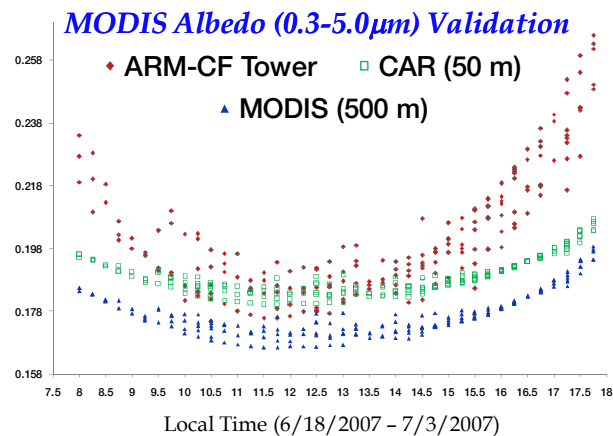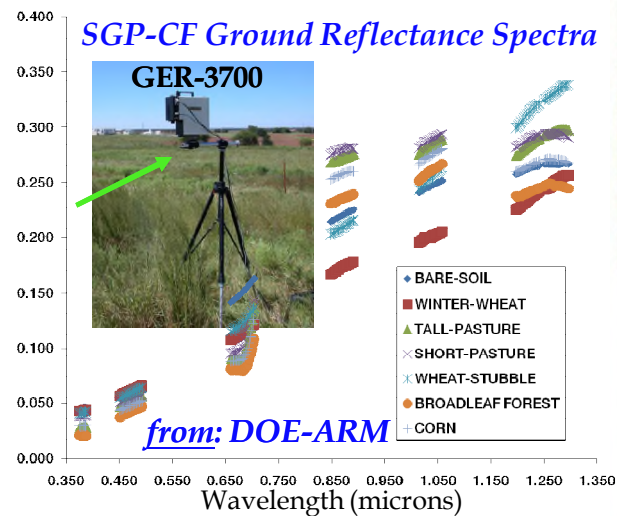tower measurements…

and airborne measurements…

Bondville, IL

CLASIC'07: ARM Southern Great Plains (SGP) Site

Coincident
Surface BRF and Albedo from Ground, Aircraft, and Satellite.

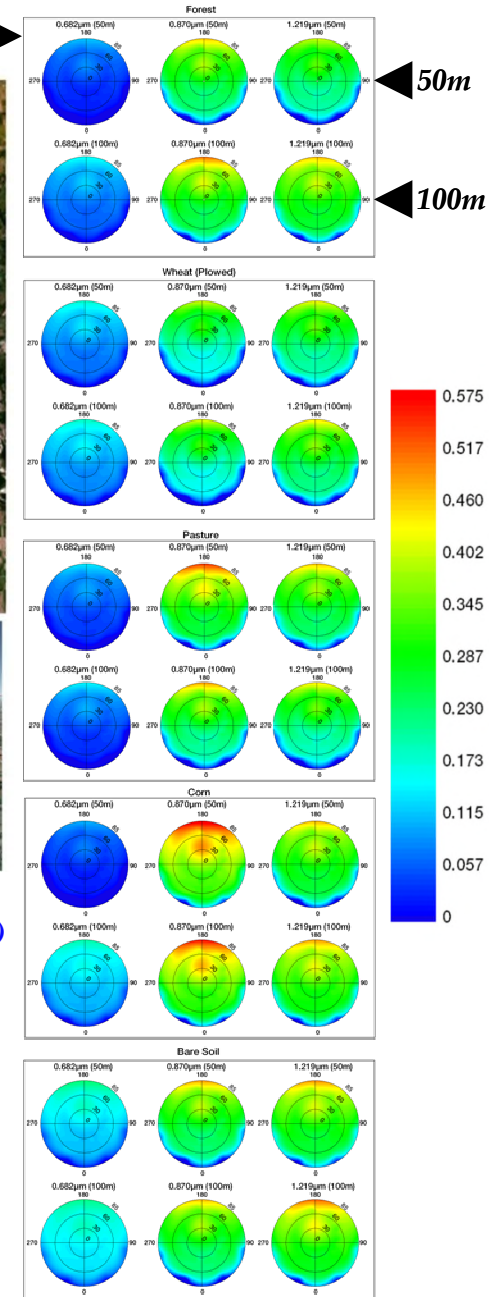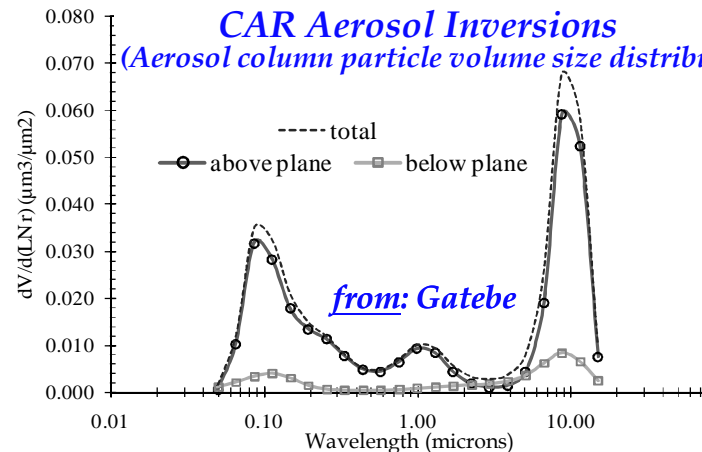## Best ever
Multi-scale observations of the SGP EOS Core Site.

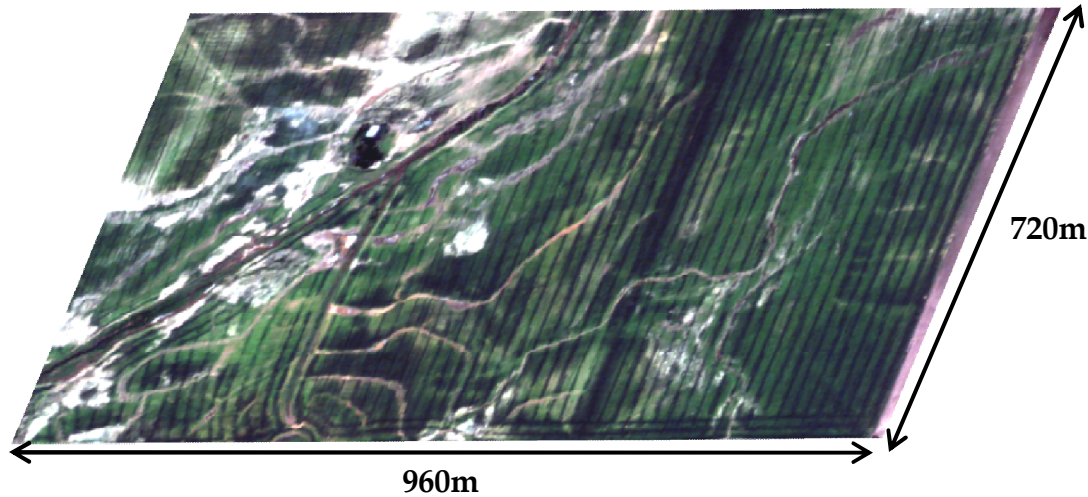**CAR** *Spectral BRFs over SGP Site, June 24, 2007*

a. **Flight #1928**

Ponca City, OK

SGP-CF

10.0 km

b. **SGP Site**

c. **BRDF Circles**

[0.2, 4.0km]

1.5 km

SGP-CF Ground Reflectance Spectra

GER-3700

- ◆ BARE-SOIL
- ■ WINTER-WHEAT
- ▲ TALL-PASTURE
- ✕ SHORT-PASTURE
- ✳ WHEAT-STUBBLE
- ● BROADLEAF FOREST
- ＋ CORN

from: DOE-ARM

Wavelength (microns)

MODIS Albedo (0.3-5.0μm) Validation

- ◆ ARM-CF Tower
- ▲ MODIS (500 m)
- □ CAR (50 m)

Local Time (6/18/2007 – 7/3/2007)

CAR Aerosol Inversions
(Aerosol column particle volume size distribution)

$dV/d(LNr) (\mu m3/\mu m2)$

- - - - total
- ○ above plane
- ■ below plane

from: Gatebe

Wavelength (microns)

Forest

50m

100m

Wheat (Plowed)

Pasture

Corn

Bare Soil

0.575
0.517
0.460
0.402
0.345
0.287
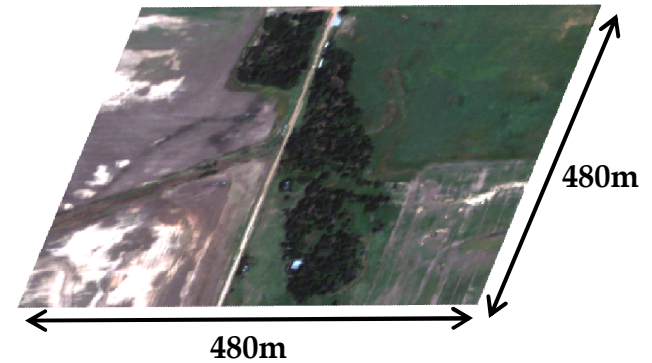0.230
0.173
0.115
0.057
0

CAR Multi-Scale Land Science Products: _Proof of Concept_

Plot #1: Corn
(36.6186N, -97.4916E)

720m

960m

Plot #2: Mixed Field
(36.6183N, -97.4939E)

480m

480m

Plot #4: Stubble
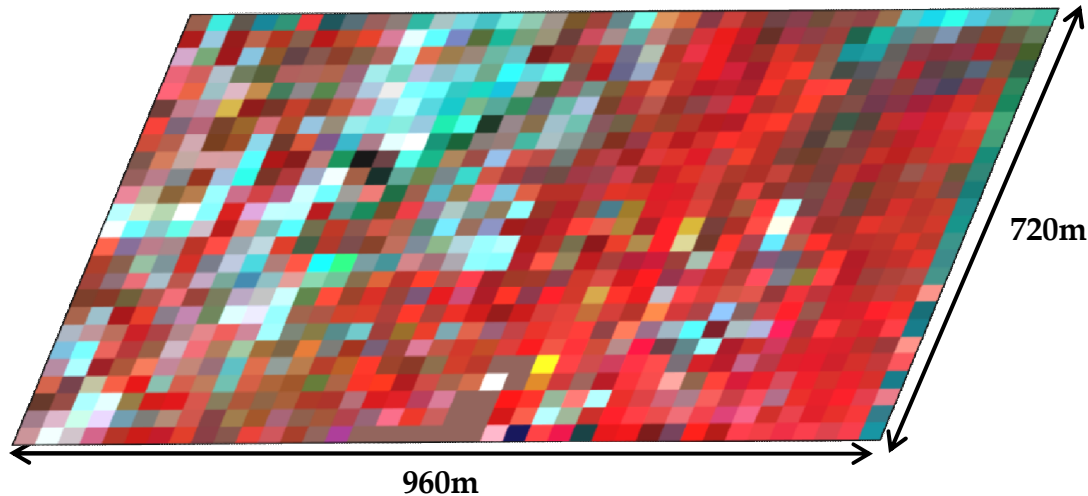**(36.6183N, -97.4939E)**

720m

480m

Plot #3: Senescent Winter Wheat
(36.6117N, -97.5208E)

720m

720m
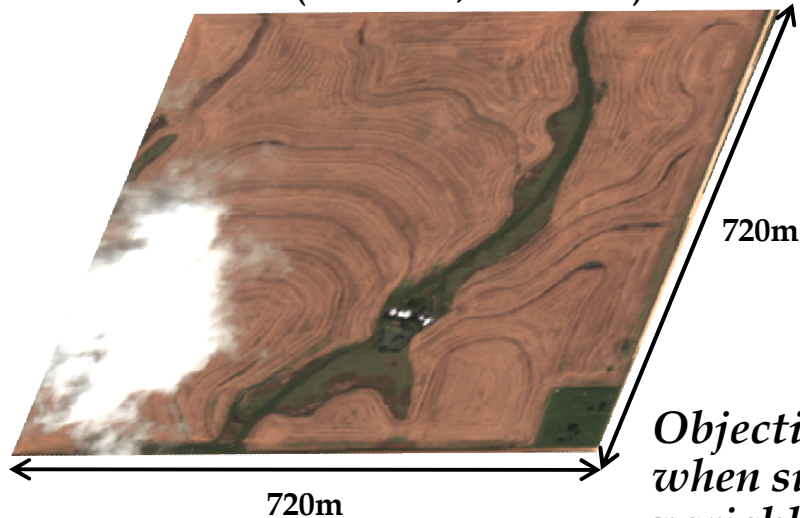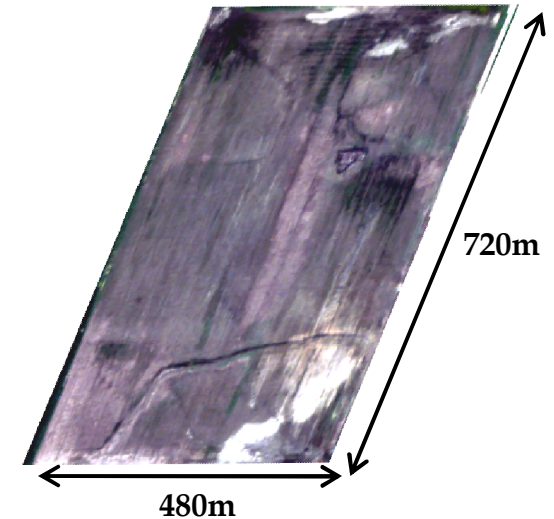
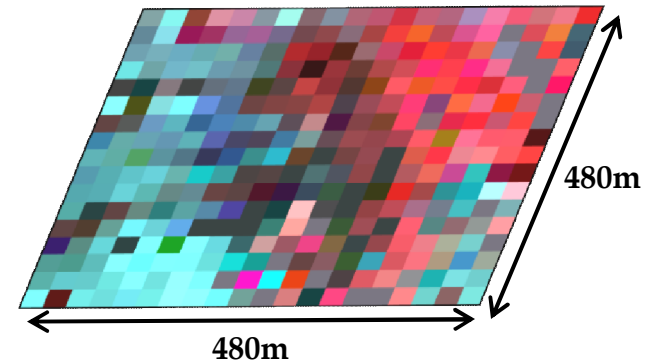_Objective: To characterize the uncertainties that arise when sub-pixel differences in terrestrial essential climate variables are aggregated into a coarser-scale satellite pixel._
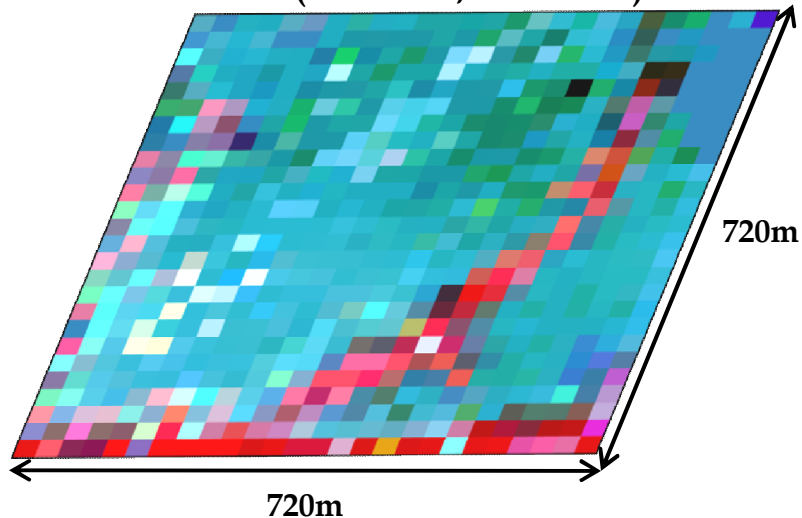
CLASIC'07: CAR Multi-Scale Surface BRF Subsets

Plot #1: Corn
(36.6186N, -97.4916E)

720m
960m

Plot #2: Mixed Field
(36.6183N, -97.4939E)

480m
480m

Plot #4: Stubble
(36.6183N, -97.4939E)

720m
480m

CAR @ 30m
(e.g., ETM+, EO-1, and LDCM)

Plot #3: Senescent Winter Wheat
(36.6117N, -97.5208E)

720m
720m

RGB = [0.870μm, 0.682μm, 0.472μm]
Ross-Li BRDF Model
VZA= Nadir; SZA=LSN

CLASIC'07: CAR Multi-Scale Surface BRF Subsets
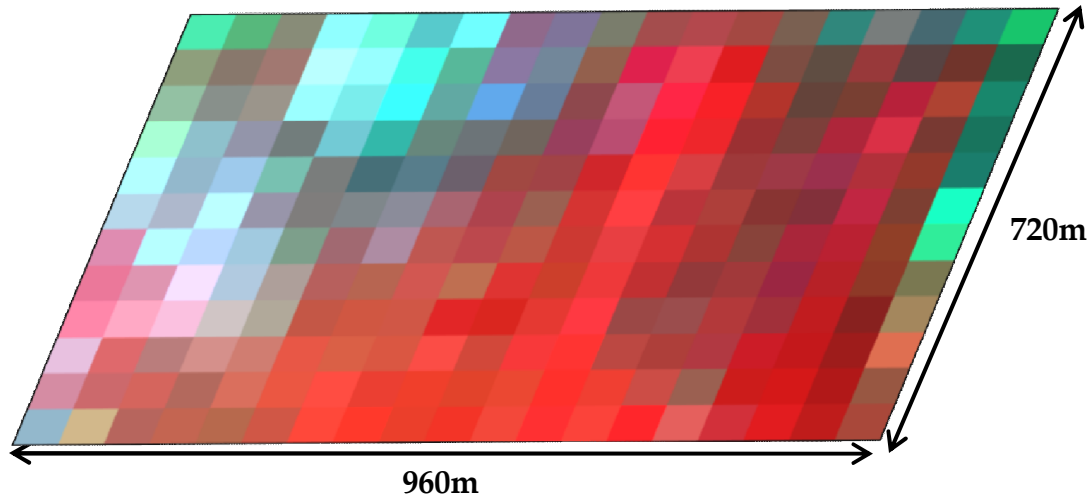
Plot #1: Corn
(36.6186N, -97.4916E)
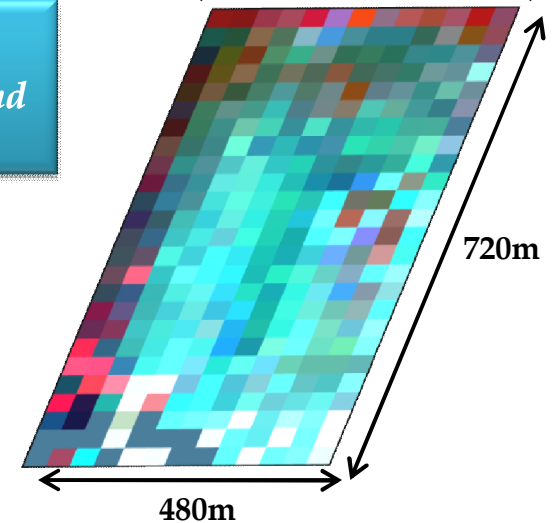
720m

960m

Plot #2: Mixed Field
(36.6183N, -97.4939E)

480m

480m
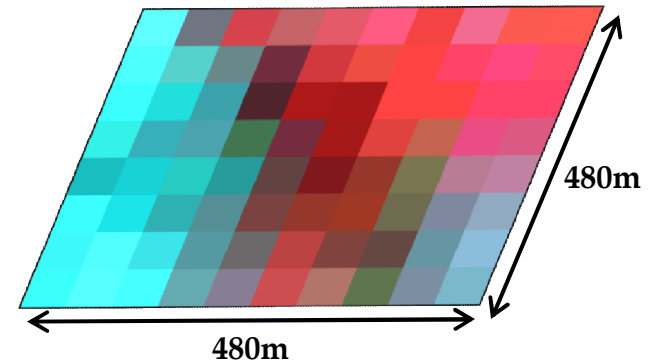
CAR @ 60m
(e.g., AWiFS, Landsat/LDCM TIRS, and HyspIRI)

Plot #4: Stubble
(36.6183N, -97.4939E)

720m

480m

Plot #3: Senescent Winter Wheat
(36.6117N, -97.5208E)

720m

720m

RGB = [0.870μm, 0.682μm, 0.472μm]
Ross-Li BRDF Model
VZA= Nadir; SZA=LSN

*Note: These are *independent* retrievals (@ 60m) from CAR.*

CLASIC'07: CAR Multi-Scale Surface BRF Subsets

Plot #1: Corn
(36.6186N, -97.4916E)

720m

960m

Plot #2: Mixed Field
(36.6183N, -97.4939E)

480m

480m

Plot #3: Senescent Winter Wheat
(36.6117N, -97.5208E)

720m

720m
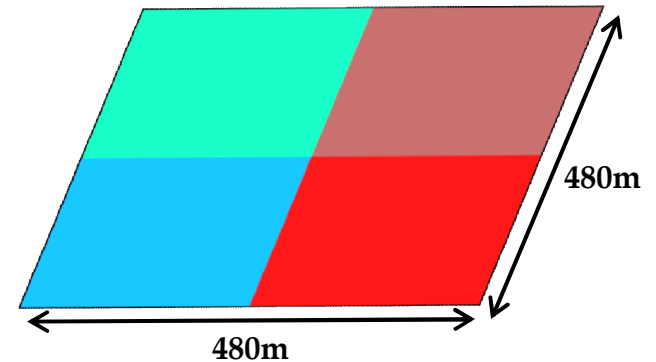
CAR @ 240m
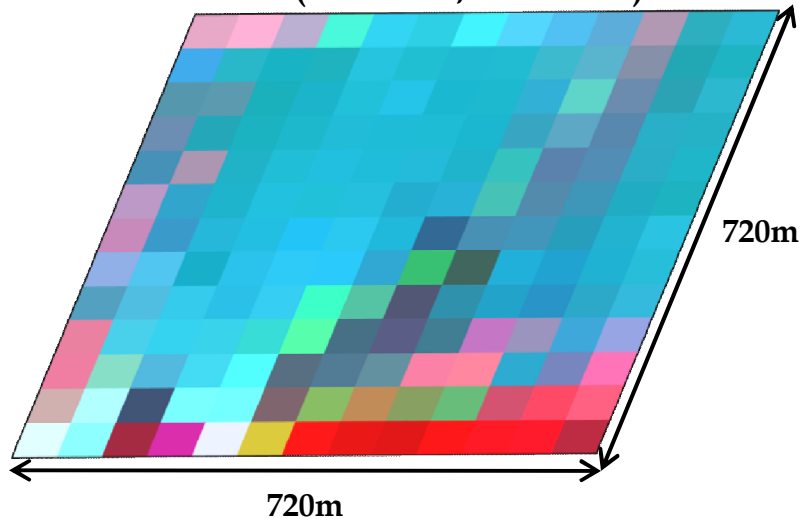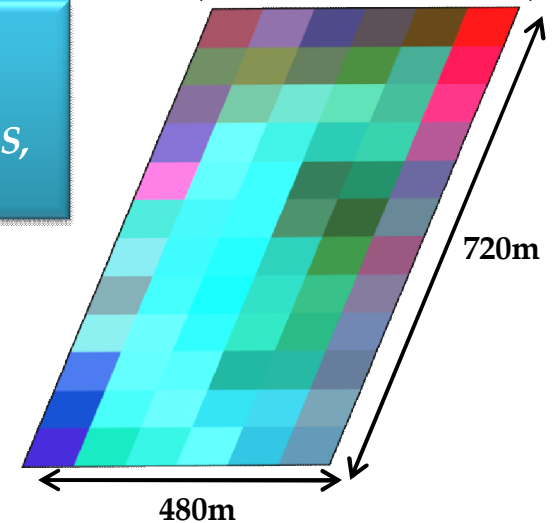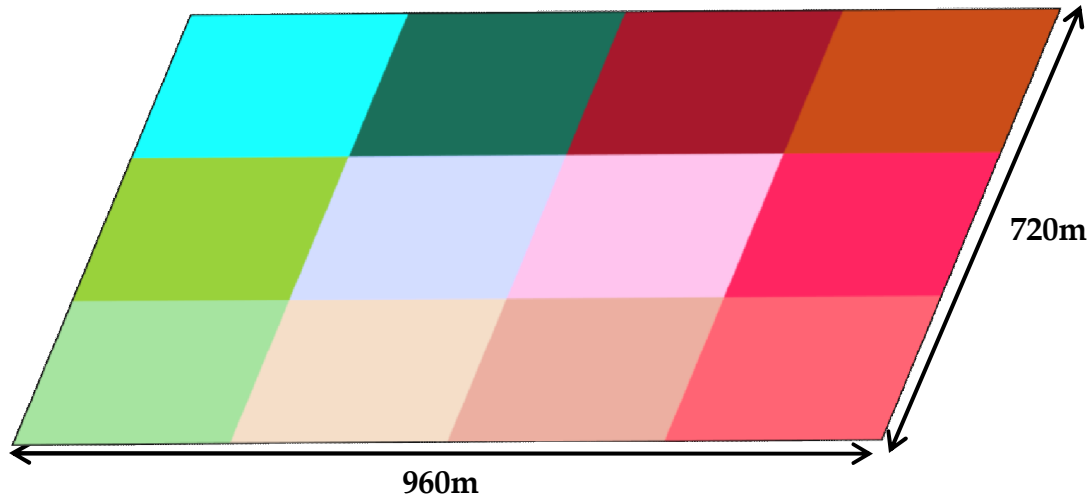*(e.g., MISR & MODIS)*

Plot #4: Stubble
(36.6183N, -97.4939E)

720m

480m

RGB = [0.870μm, 0.682μm, 0.472μm]
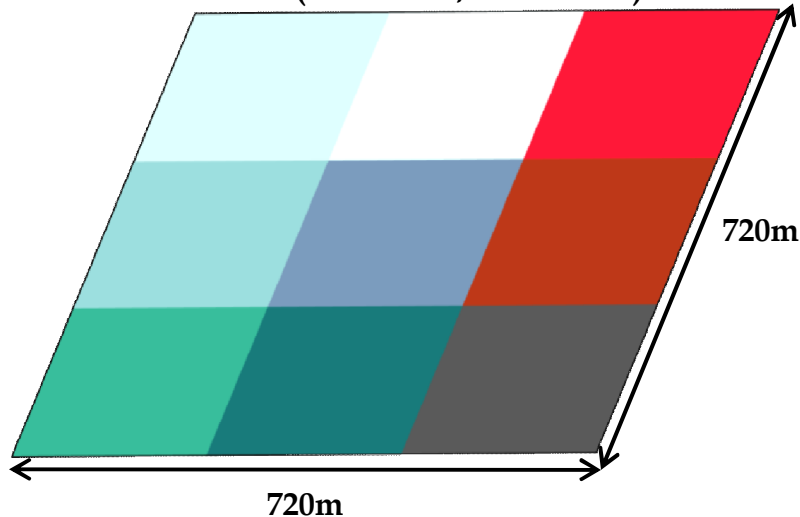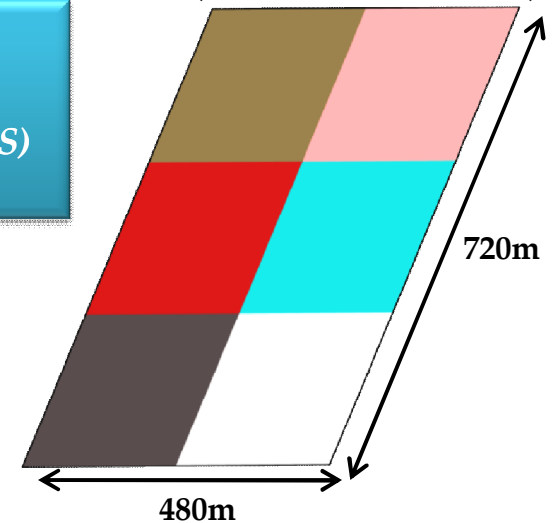**Ross-Li BRDF Model**
VZA= Nadir; SZA=LSN

Note: These are *independent* retrievals (@ 240m) from CAR.

Uncertainty due to Spatial Scaling Effects and Measurement Differences Between Satellite Retrievals

CAR @ 60m [*r*] vs. CAR @ 30m [*θ*]

Plot #1 Corn: BRF($\lambda = 0.682\mu m$)
Plot #2 Mixed: BRF($\lambda = 0.682\mu m$)
Plot #3 Wheat: BRF($\lambda = 0.682\mu m$)
Plot #4 Stubble: BRF($\lambda = 0.682\mu m$)

CAR @ 240m [*r*] vs. CAR @ 30m [*θ*]

Plot #1 Corn: BRF($\lambda = 0.682\mu m$)
Plot #2 Mixed: BRF($\lambda = 0.682\mu m$)
Plot #3 Wheat: BRF($\lambda = 0.682\mu m$)
Plot #4 Stubble: BRF($\lambda = 0.682\mu m$)

Abs. RMSE

0.074
0.067
0.061
0.054
0.047
0.040
0.034
0.027
0.020
0.014
0.007
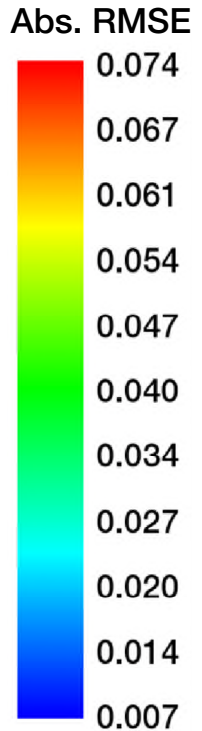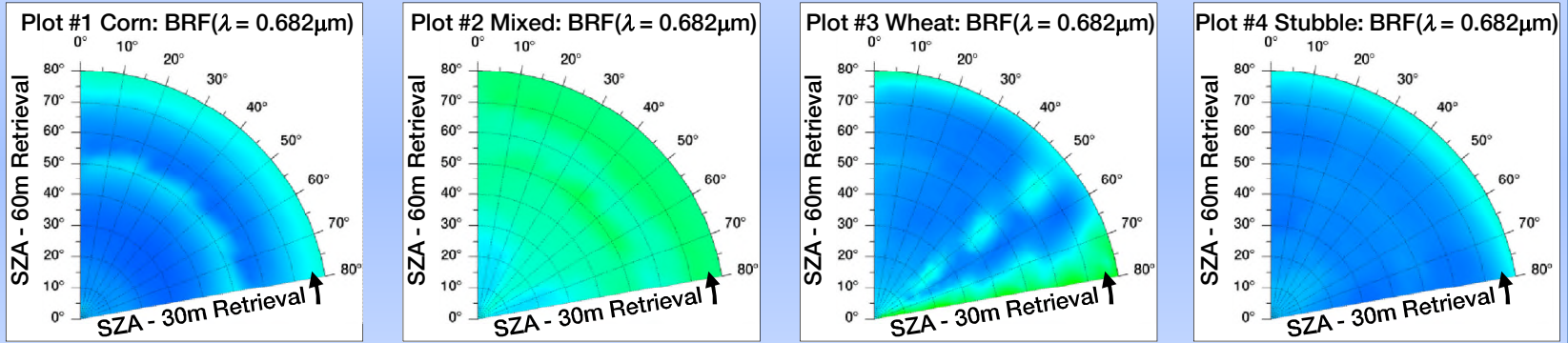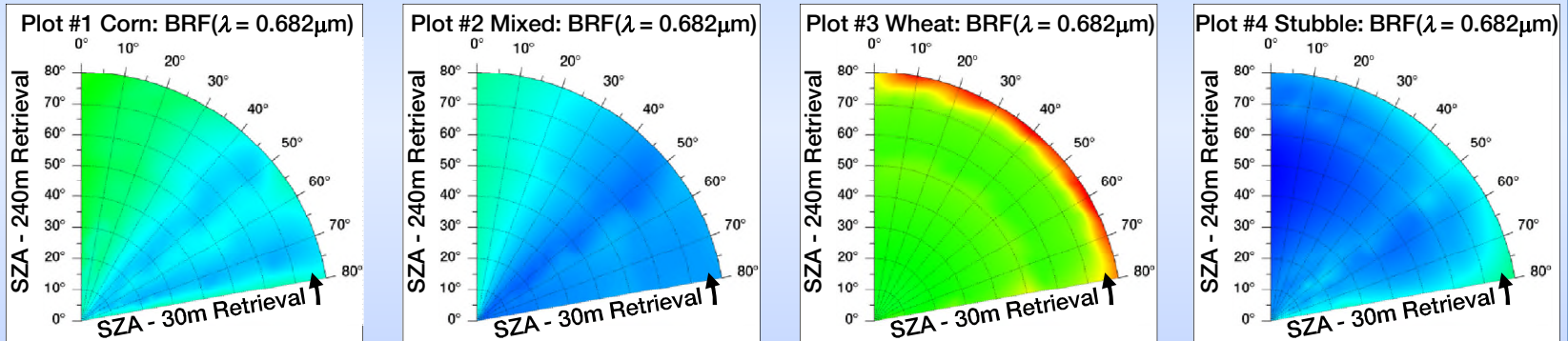
$\lambda = 0.682\mu m$
Relative Azimuth Angle = 0°
CAR@30m VZA = 15°
CAR@60m VZA = 15°
CAR@240m VZA = 45°

Uncertainty due to Spatial Scaling Effects and Measurement Differences Between Satellite Retrievals

CAR @ 60m [r] vs. CAR @ 30m [θ]

Plot #1 Corn: BRF($\lambda = 0.870\mu m$)
Plot #2 Mixed: BRF($\lambda = 0.870\mu m$)
Plot #3 Wheat: BRF($\lambda = 0.870\mu m$)
Plot #4 Stubble: BRF($\lambda = 0.870\mu m$)

CAR @ 240m [r] vs. CAR @ 30m [θ]

Plot #1 Corn: BRF($\lambda = 0.870\mu m$)
Plot #2 Mixed: BRF($\lambda = 0.870\mu m$)
Plot #3 Wheat: BRF($\lambda = 0.870\mu m$)
Plot #4 Stubble: BRF($\lambda = 0.870\mu m$)

Abs. RMSE

0.229
0.209
0.188
0.168
0.147
0.127
0.107
0.086
0.066
0.045
0.025
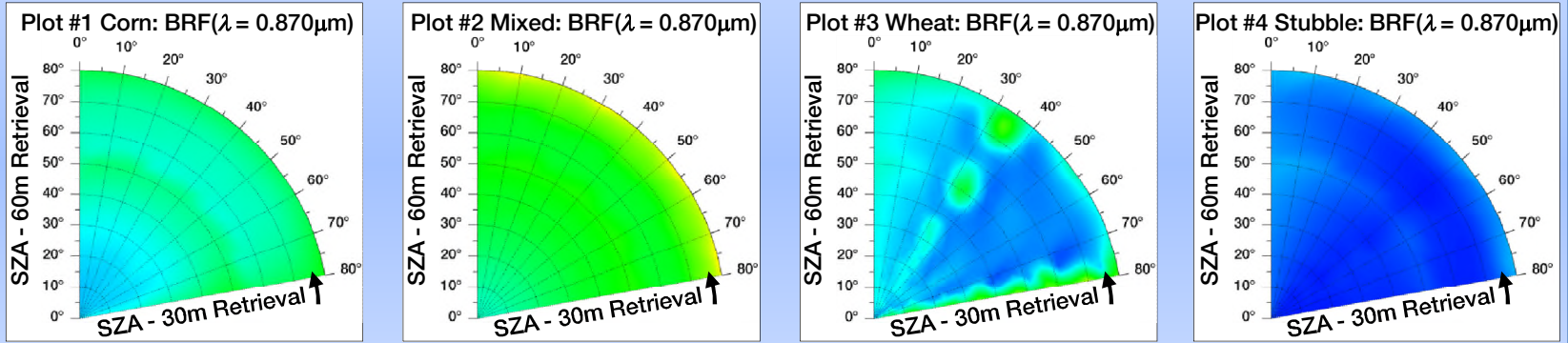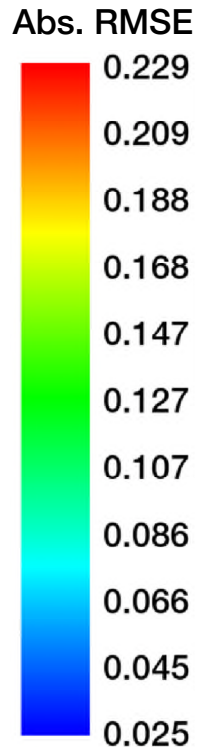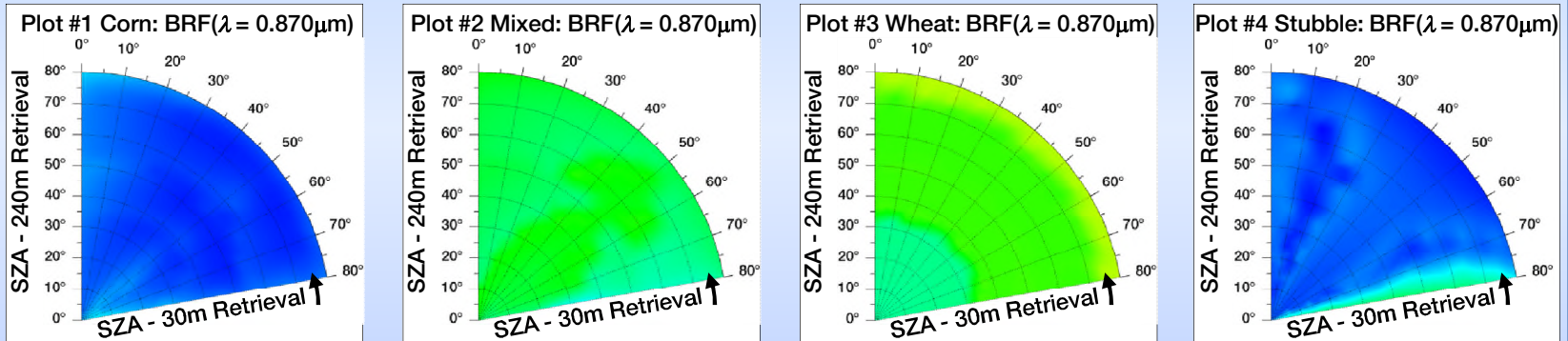
Next Steps: To relate "pixel-level" assessments to a true vegetation-related or biophysical reference (e.g., flood, drought, crop productivity).

$\lambda = 0.870\mu m$
Relative Azimuth Angle = 0°
CAR@30m VZA = 15°
CAR@60m VZA = 15°
CAR@240m VZA = 45°

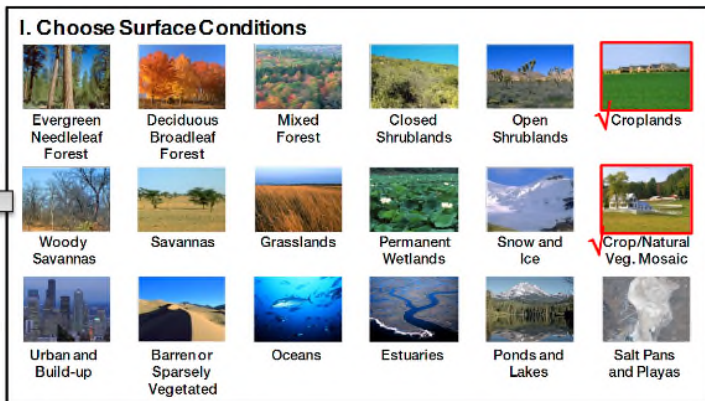# *Objective: "To Improve Data Access and Availability of Existing and Future CAR Land Science Products"*

I. Choose Surface Conditions

Evergreen Needleleaf Forest · Deciduous Broadleaf Forest · Mixed Forest · Closed Shrublands · Open Shrublands · √Croplands

Woody Savannas · Savannas · Grasslands · Permanent Wetlands · Snow and Ice · √Crop/Natural Veg. Mosaic

Urban and Build-up · Barren or Sparsely Vegetated · Oceans · Estuaries · Ponds and Lakes · Salt Pans and Playas

II. Choose Sun-View Geometry
- View Angle Range
  - CAR mode (0° to 80°)
  - Landsat/ASTER mode (0° to 15°)
  - ✓ **MODIS mode (10° to 45°)**
  - MISR mode (Nadir to 70°)
  - POLDER mode (10° to 60°)
  - Customized [0° to 85°]
- Solar Zenith Angle
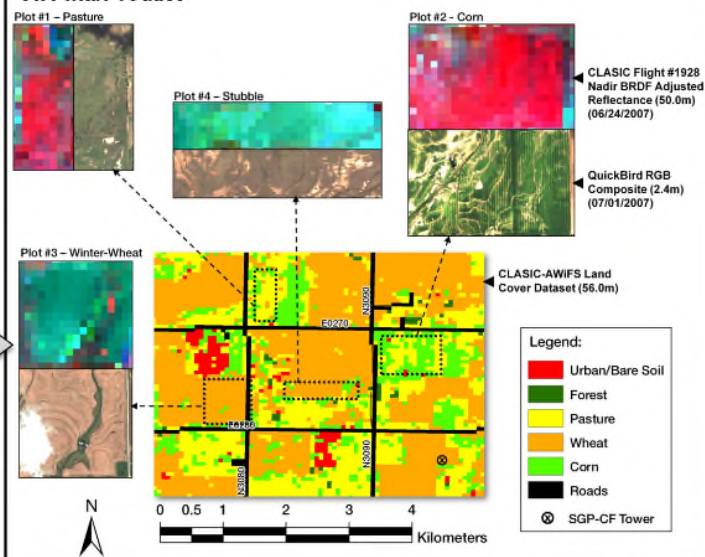 - Customized [0° to 85°]
  - ✓ **Local Solar Noon**

III. Choose Spatial/Grid Resolution (5.0-500m^2): **50m^2**

IV. Choose BRDF Model
Walthall; Roujean; Ross-Li (RTLSR); RPV/MRPV; Cox–Munk

V. Choose Ancillary Datasets
- Point/Tower Measurement
- ✓Land Cover Data
- High Spatial Resolution Imagery
  - Lansat ETM+
  - EOS-ASTER
  - EO-1 ALI
  - ✓ Quickbird (IKONOS)

VI. Final Product

Plot #1 – Pasture

Plot #4 – Stubble

Plot #2 - Corn

CLASIC Flight #1928 Nadir BRDF Adjusted Reflectance (50.0m) (06/24/2007)

QuickBird RGB Composite (2.4m) (07/01/2007)

Plot #3 – Winter-Wheat

CLASIC-AWiFS Land Cover Dataset (56.0m)

Legend:
- Urban/Bare Soil
- Forest
- Pasture
- Wheat
- Corn
- Roads
- ⊗ SGP-CF Tower

N

0 0.5 1   2   3   4   Kilometers

- *Data subsetting & validation tools can be used to generate "user-customized" CAR data products.*

- *Following CEOS-WGCV protocols:*
  - *"Spoon-feed" CAR datasets in easy file formats (e.g. GeoTIFF and ASCII);*
  - *Use common projections;*
  - *Quality assurance flags;*
  - *Provide online product documentation;*
  - *Incorporate user feedback.*

Example: CAR 50m Nadir BRDF-Adjusted Reflectance over croplands, using the MODIS sensor's view geometry, and the Ross-Li BRDF model.

Summary

NASA's Cloud Absorption Radiometer Provides an Efficient Means to:

- *Address satellite retrieval uncertainties (i.e., calibration, atmospheric correction, and scaling effects) in a complete and systematic manner.*

- *Characterize measurement differences between satellite sensors and between sensors and in-situ measurements.*

- *Improve our understanding of the behavior of complex terrestrial ecosystems (e.g., permanent wetlands and tropical savannas) with respect to their ecological functioning and vegetation structure.*

Bondville, IL

NASA